Semiconductor & Display Trends

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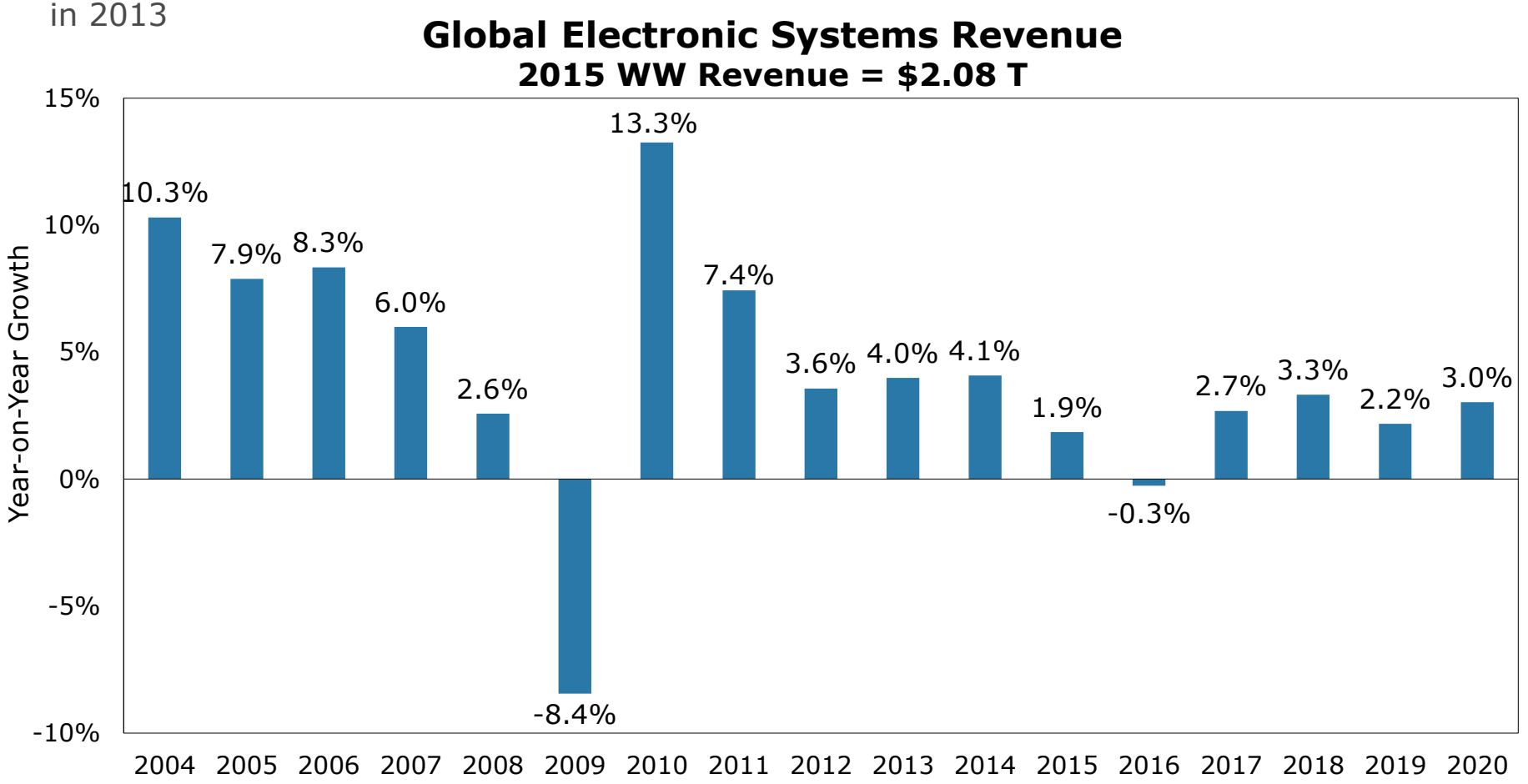
Electronics & semiconductor forecast outlook

The Start of a New Cycle

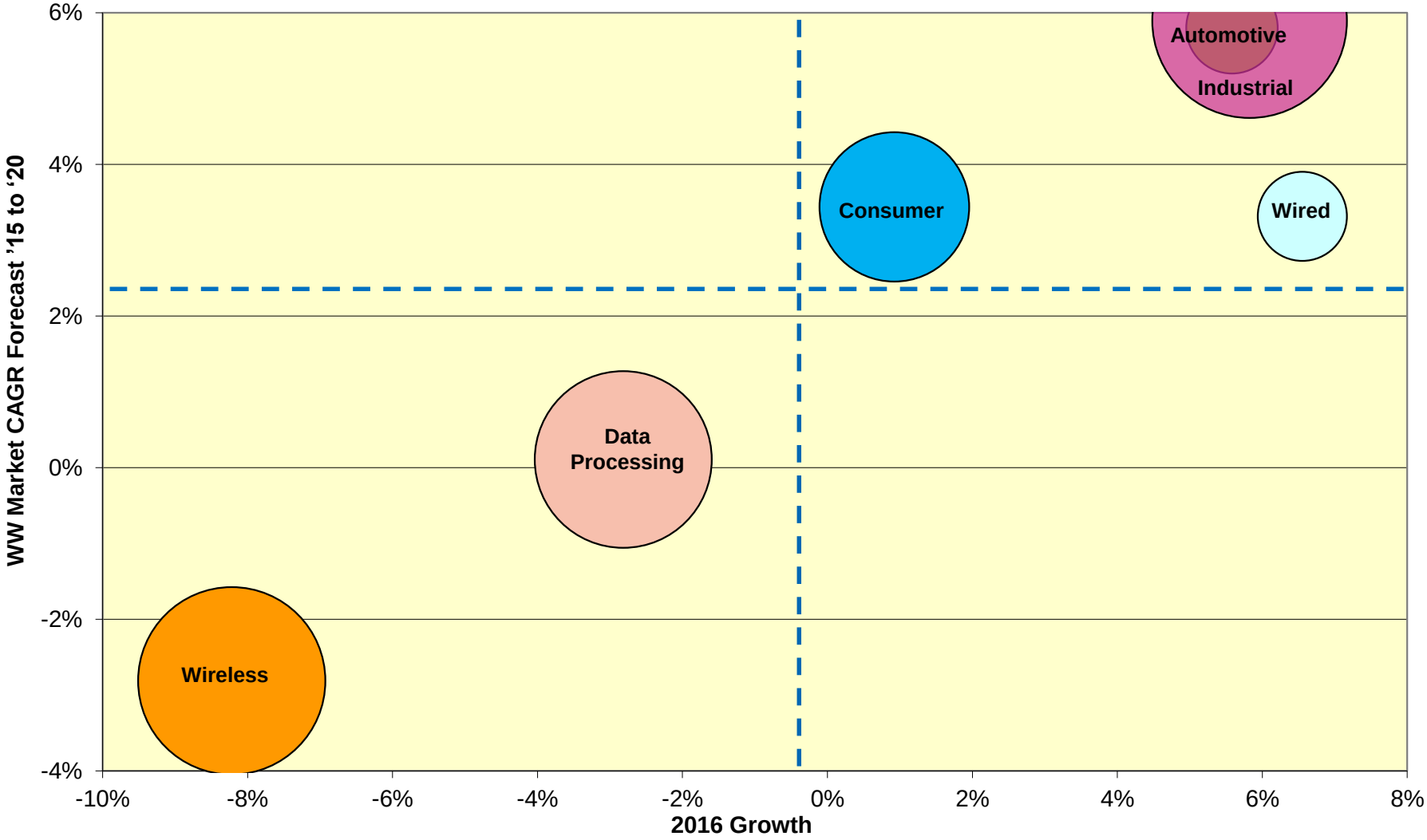
Electronics market – Growth goes negative for 2nd time in 14 years

- Five year CAGR = 2.2%
- Industrial Electronics leads growth followed by Automotive, Consumer & Wired Comm
- Industrial Electronics passed Data Processing as largest market in 2012; Wireless followed in 2013



Source – IHS *Application Market Forecast Q3 2016*

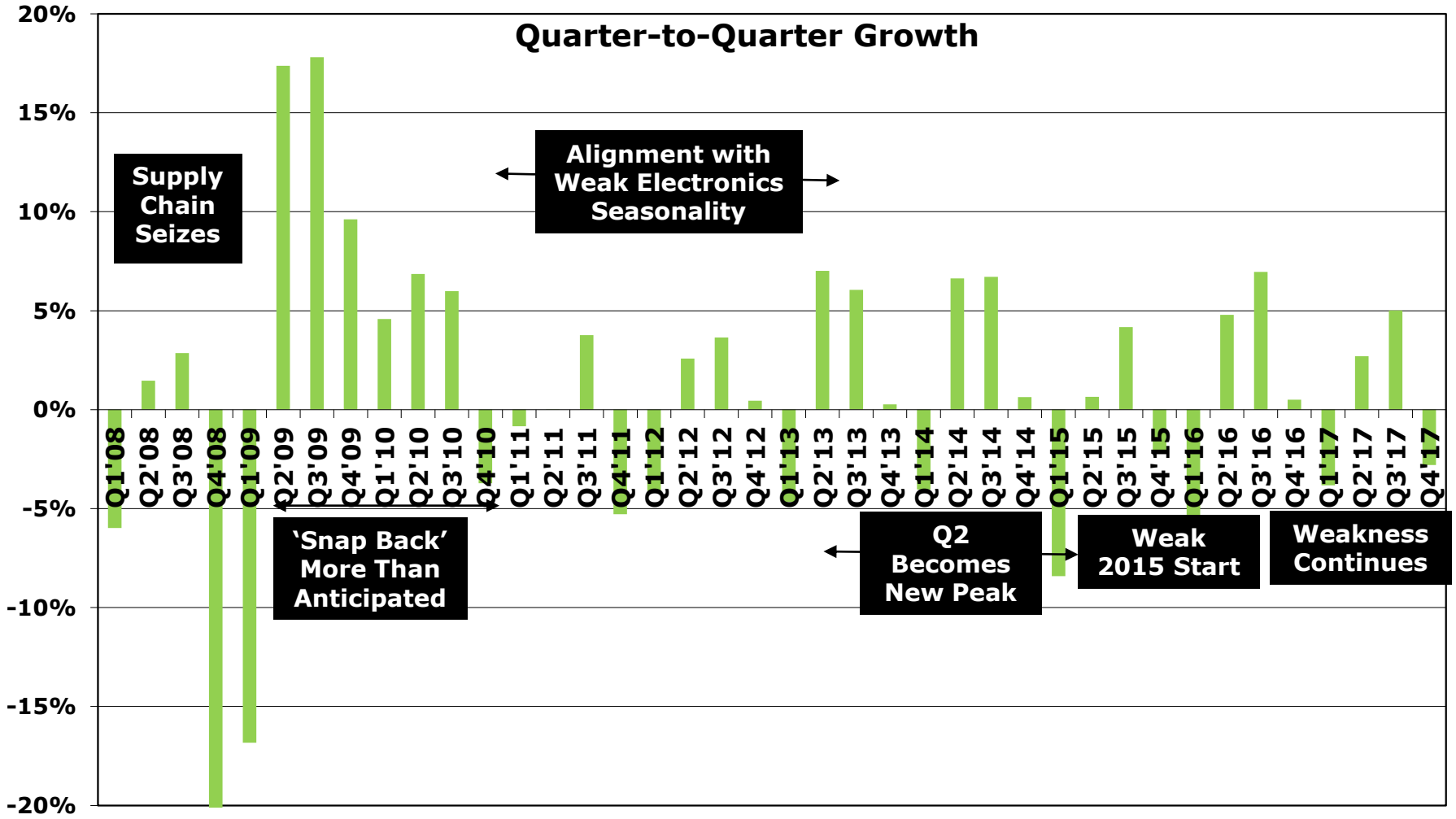
Electronics growth weighed down by Wireless & Data Processing



Source – IHS *Application Market Forecast Q3 2016*

Quarterly semiconductor forecast

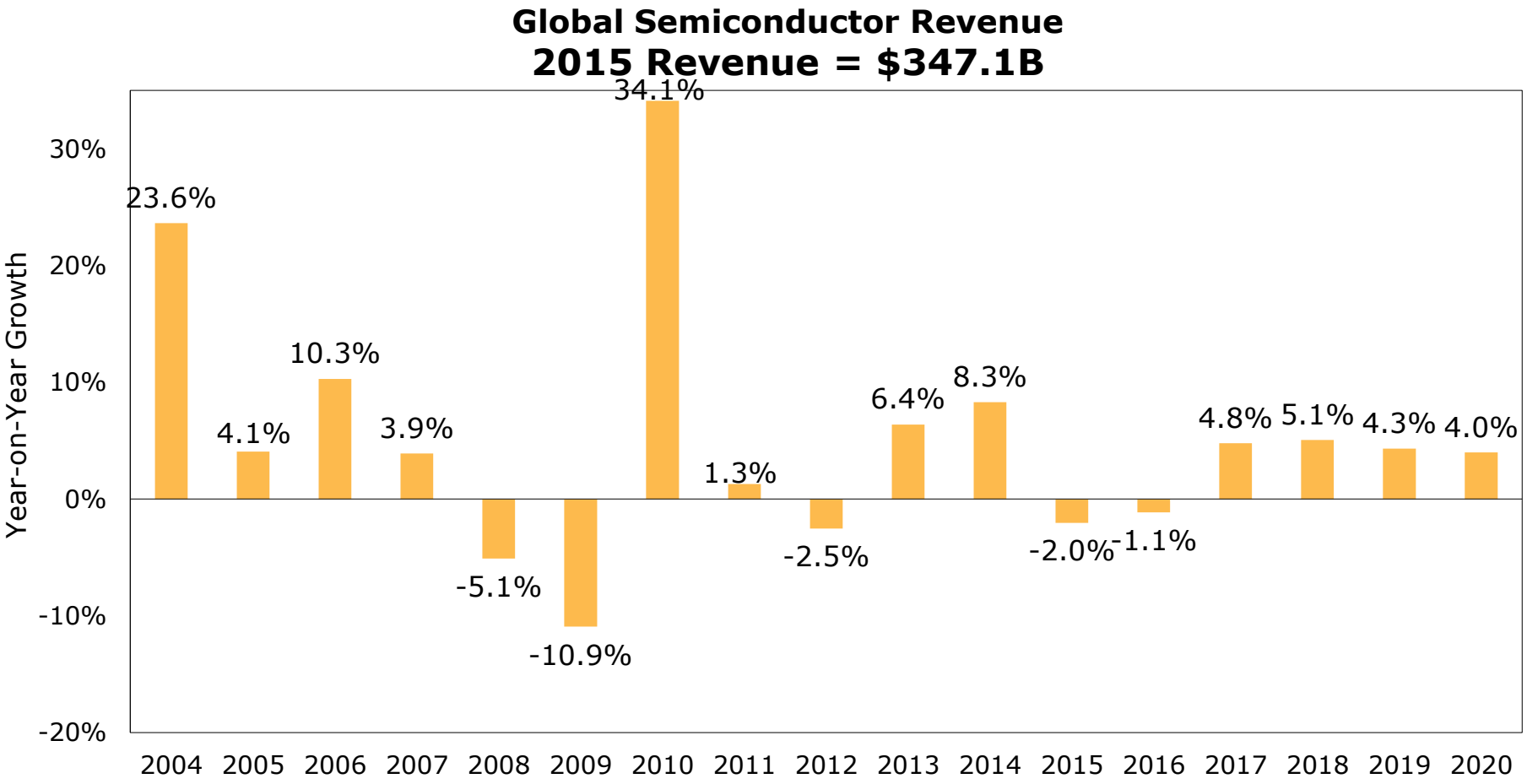
Q2 & Q3 2016 surge to solid growth; Boost full year to only -1.1% decline



Source – IHS *Application Market Forecast Q3 2016*

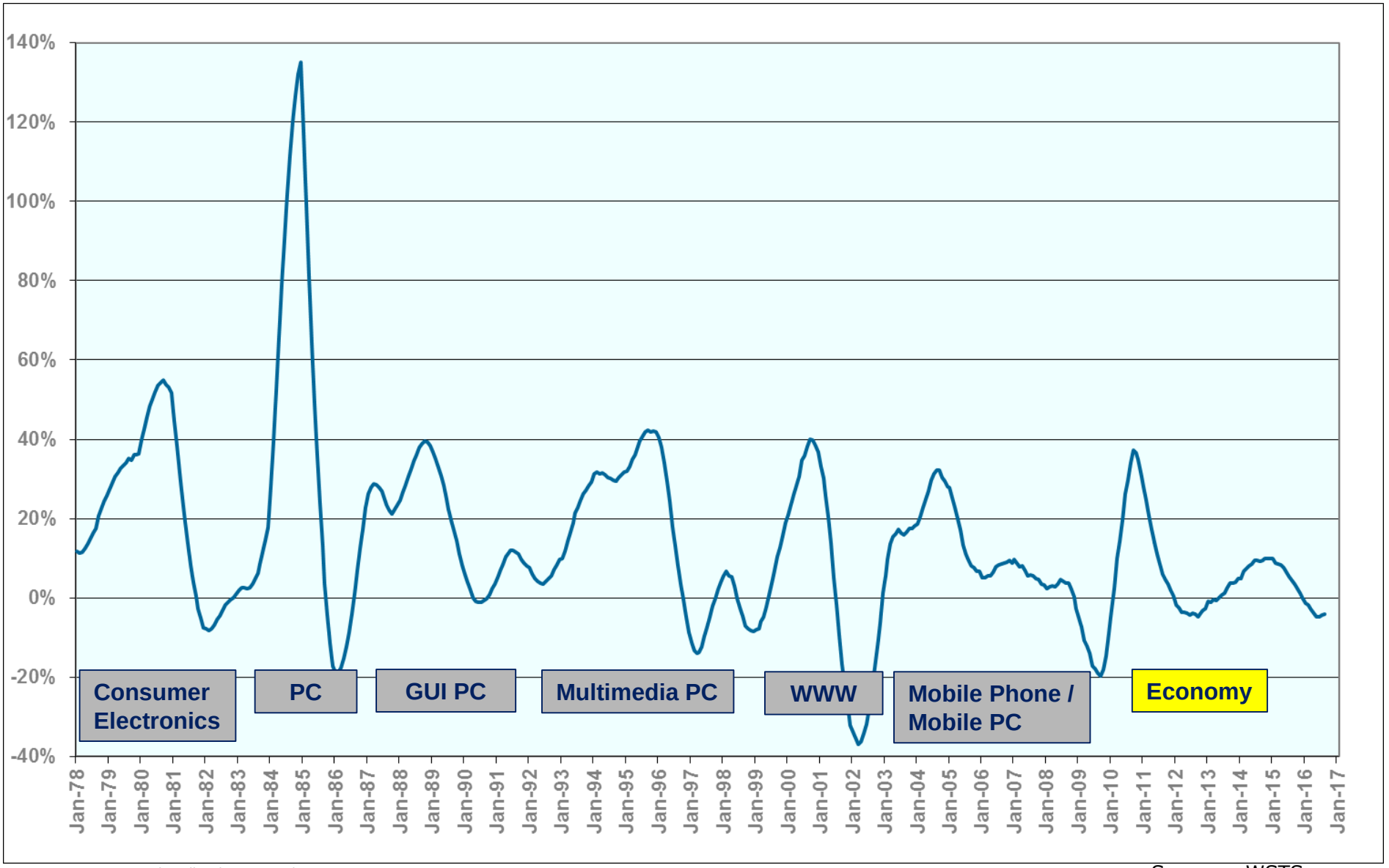
Annual semiconductor outlook

- Semiconductor market growth outlook – Next four years challenging
  - June 2016 begins tenth semiconductor industry cycle– mid-single digit growth
  - Long-term outlook sees five-year CAGR of only 3.4%



Source – IHS *Application Market Forecast Q3 2016*

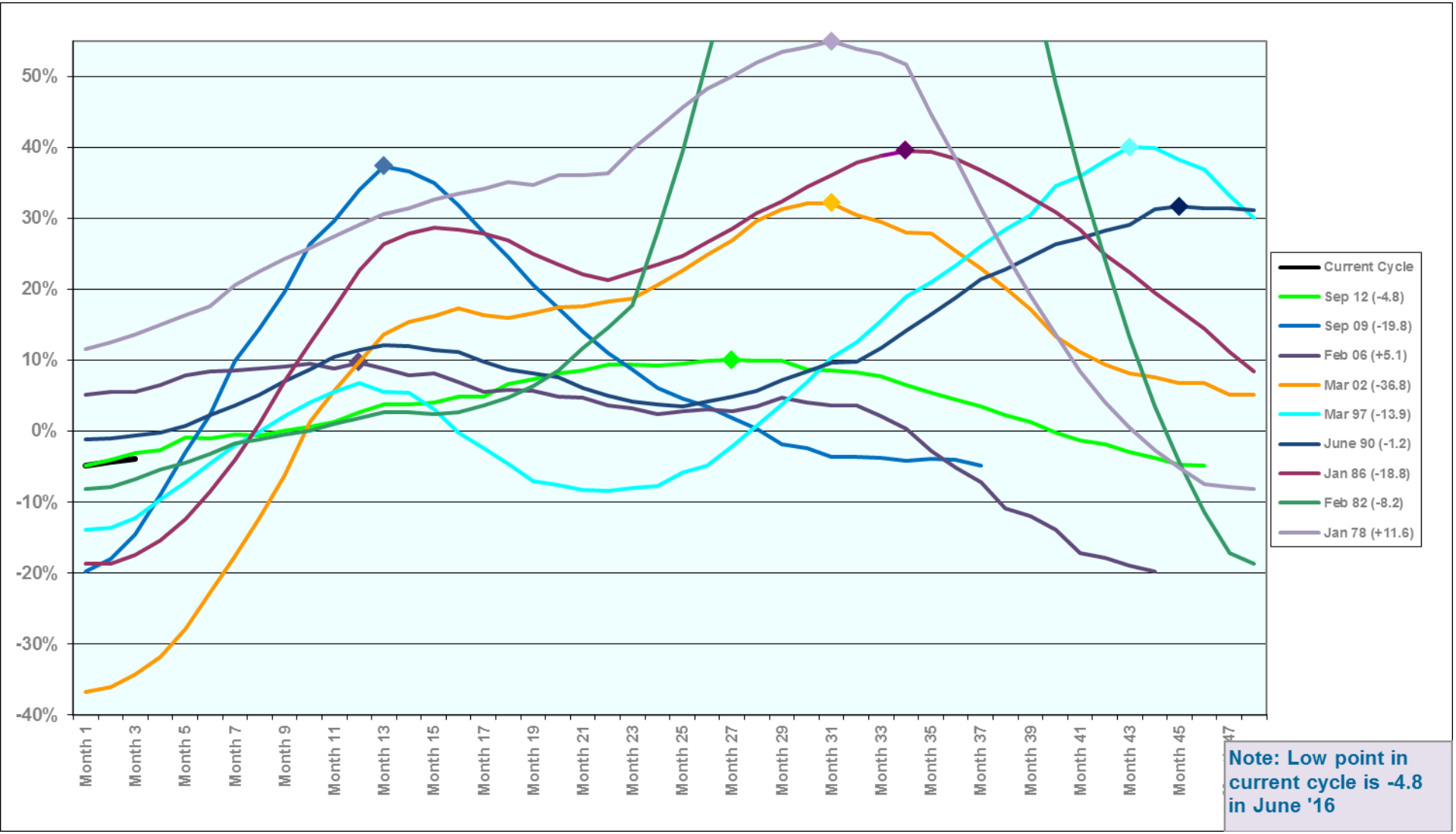
Historical 12 month moving average



Source – WSTS

June 2016 – Start of the tenth semiconductor cycle

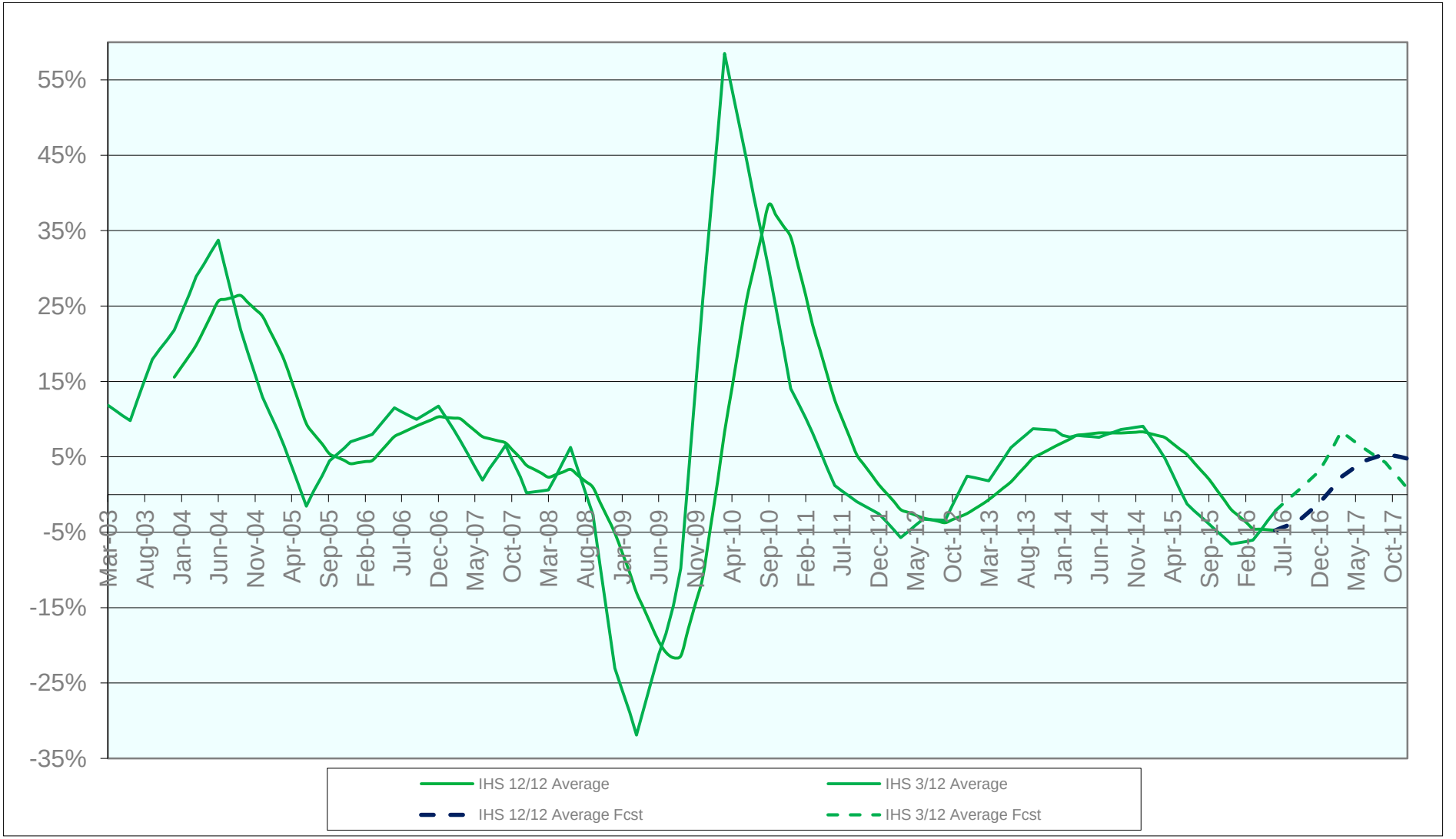
Most cycles last roughly four years



Note: Low point in current cycle is -4.8 in June '16

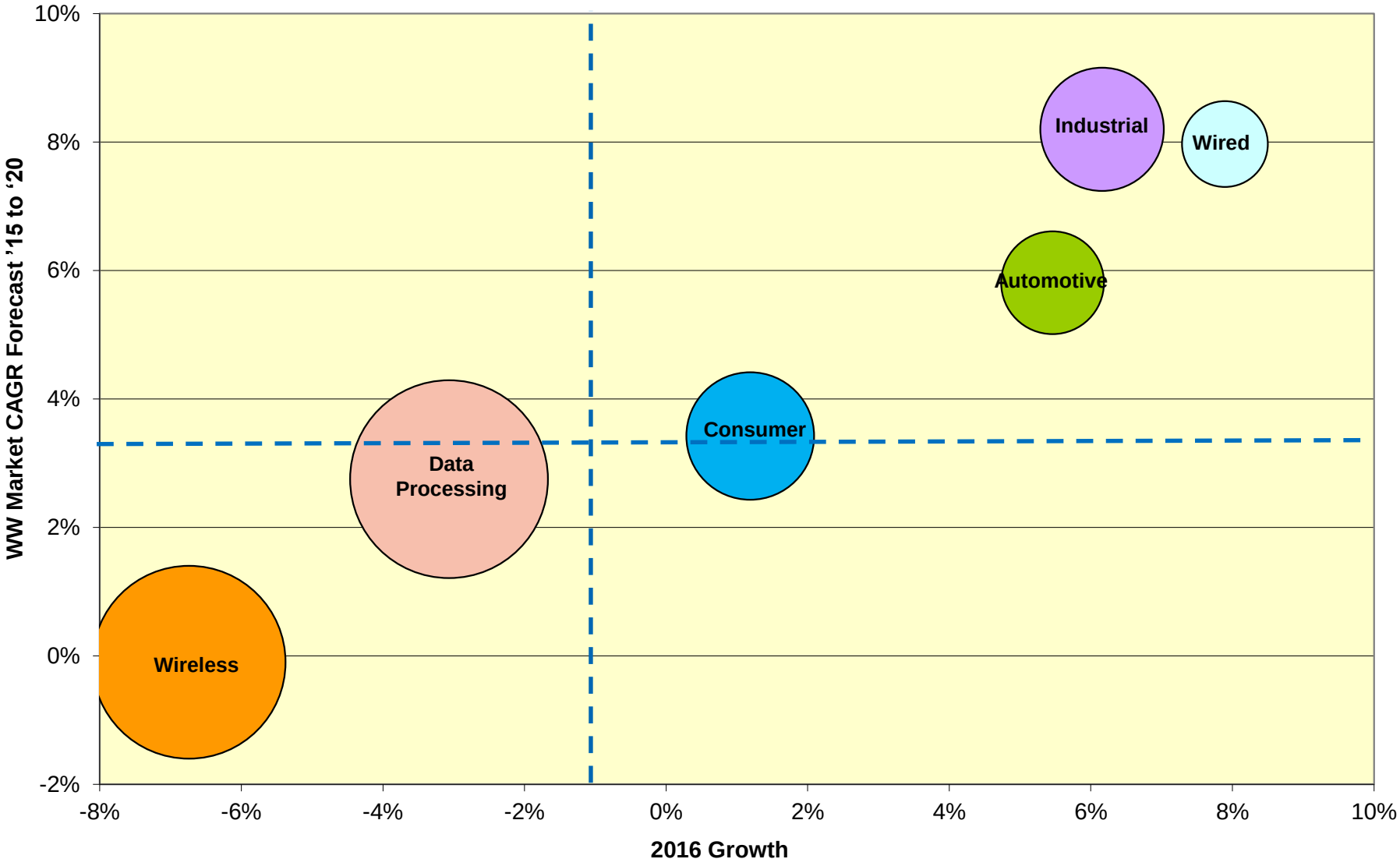
Source – WSTS

3/12 and 12/12 moving averages



Source – IHS *Application Market Forecast Q3 2016*

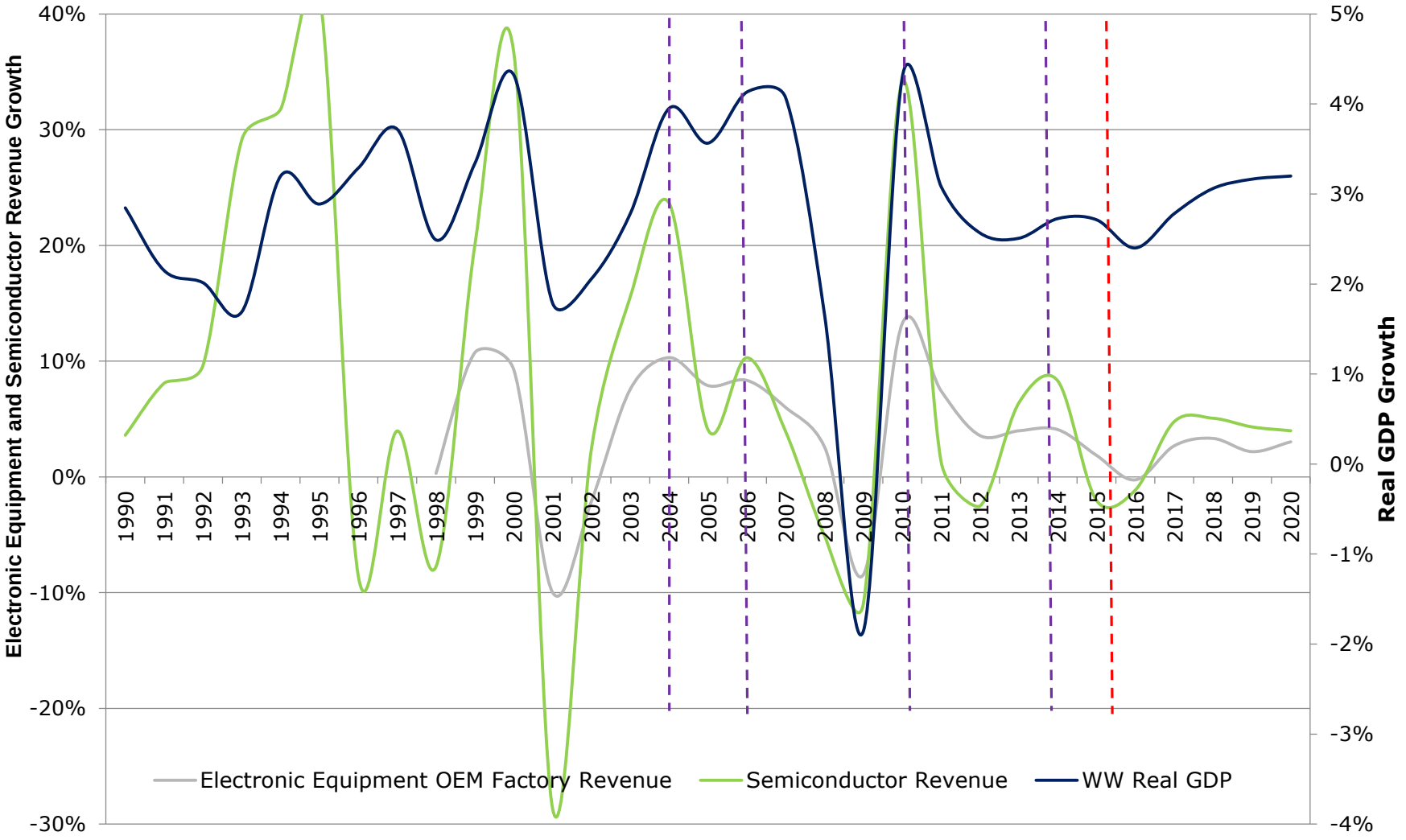
New semiconductor growth drivers for next 5 years



Source – IHS *Application Market Forecast Q3 2016*

Historic alignment between economy and electronics

Semiconductor growth profile continues to predict accurately

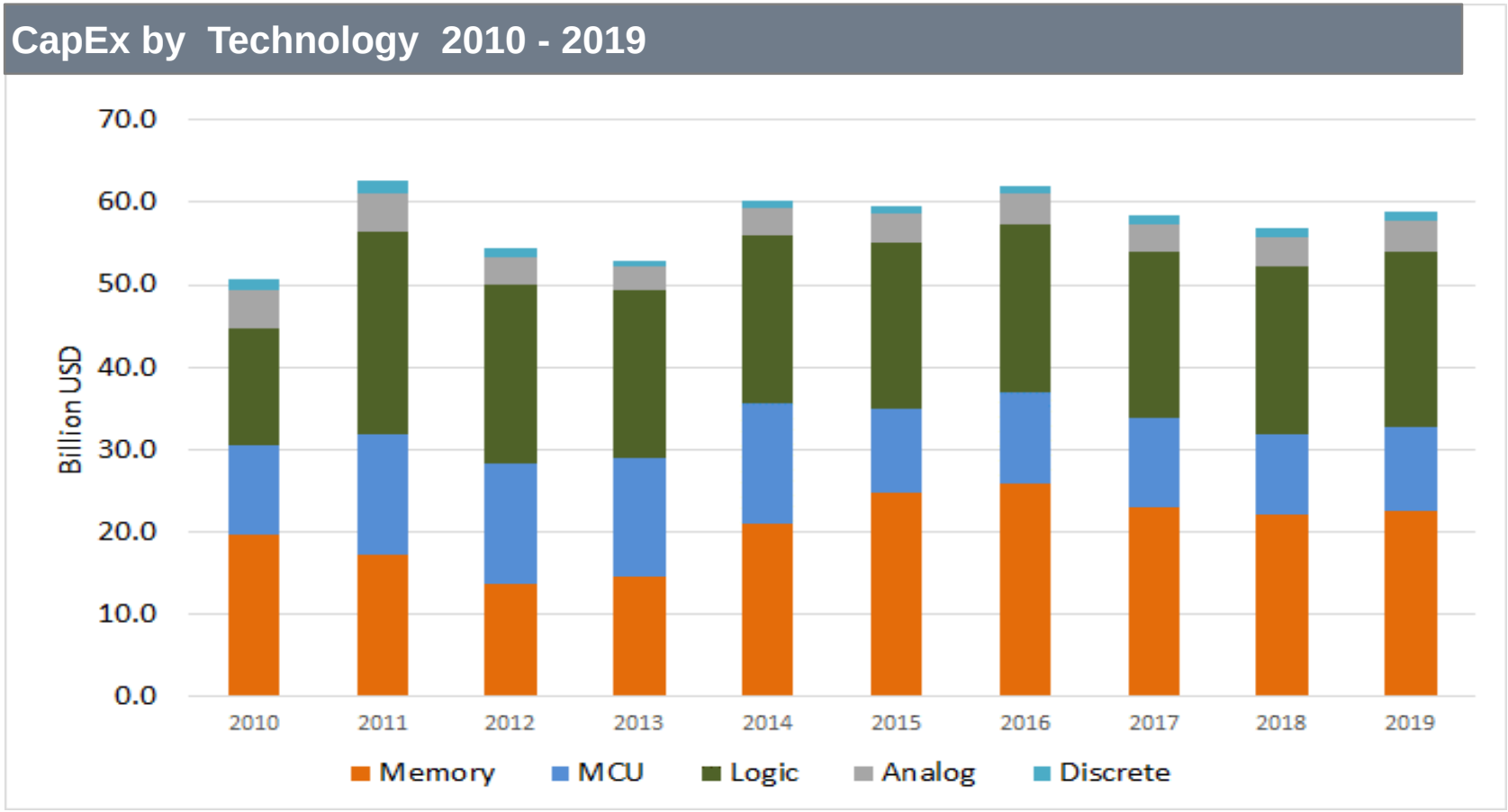


Source – IHS Global Insight and IHS Technology

Semiconductor manufacturing trends

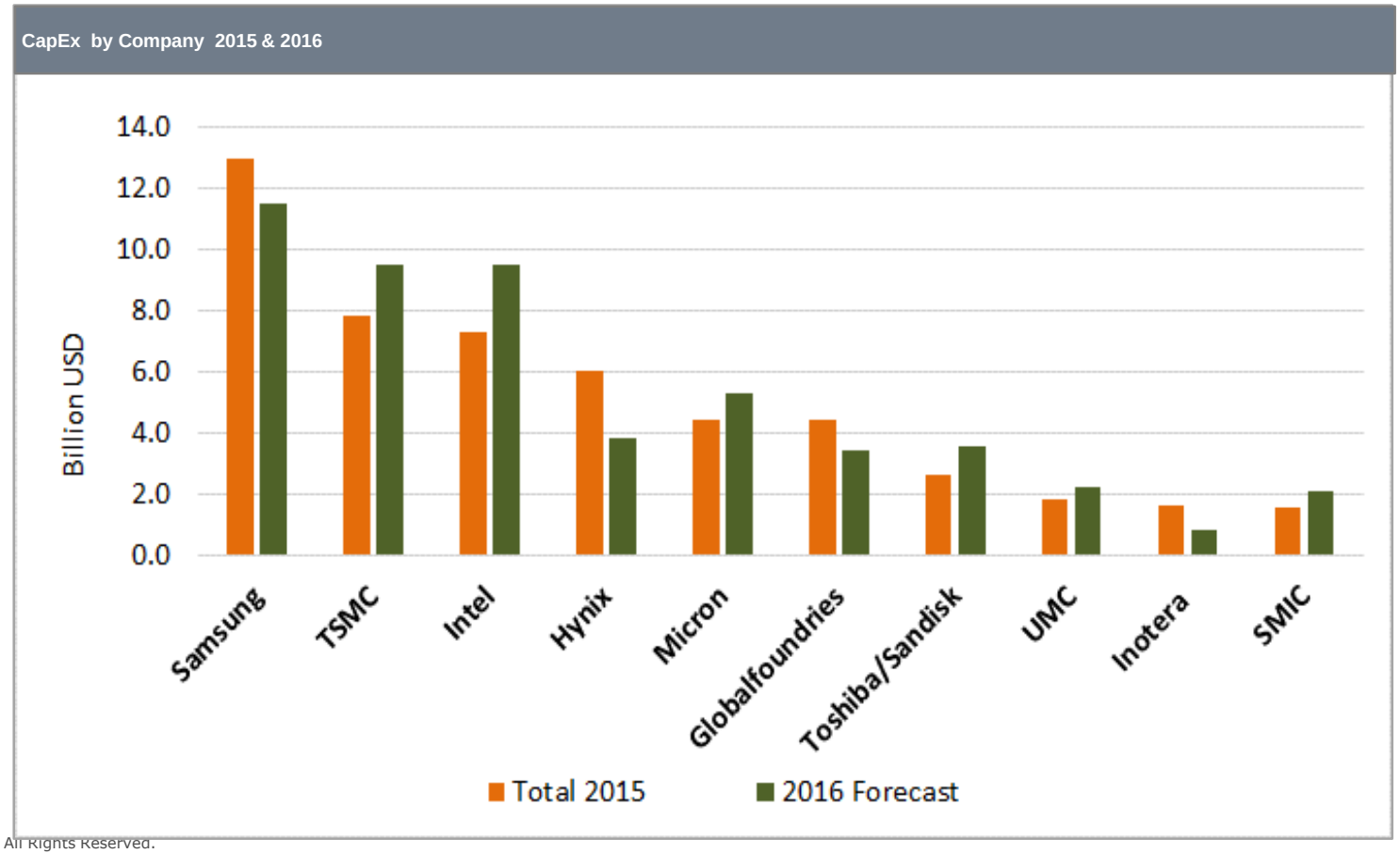
Capital expenditure provide verification for long-term growth opportunities as well as a technology roadmap

- **Expenditures supporting Logic (Foundry) and Memory continue to fuel long-term industry revenue growth**

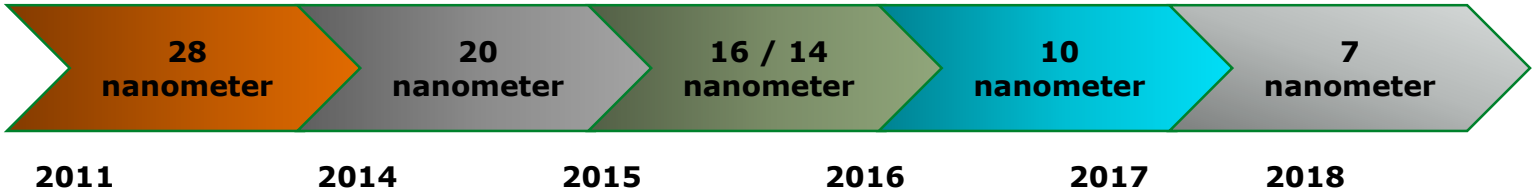


2016 capital expenditure forecast by company

- **Expenditures for capital are focused on next generation technology and expansions in China**
  - > Samsung, TSMC, Intel, Globalfoundries, UMC and SMIC are all focused on adding capacity in China



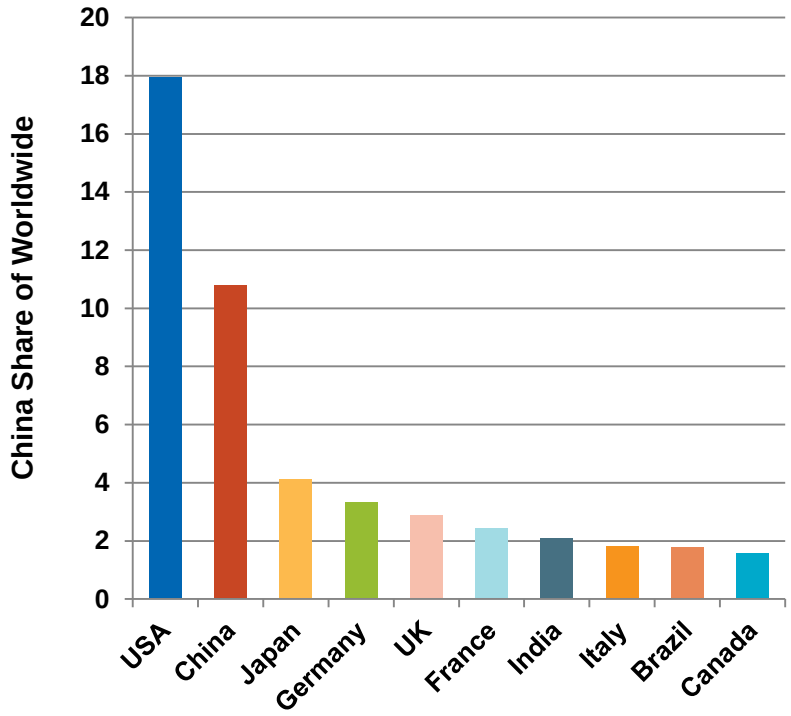
Technology migrations drive 2nd half revenue



- **Foundry revenue is driven by demand for advanced technology supporting Handsets, Graphics and computing**
  - > 28 nanometer – Apple, MediaTek, Qualcomm, Xilinx, Nvidia, AMD, Huawei, HiSilicon, Spreadtrum
  - > 20 nanometer – Apple, Qualcomm, Xilinx
  - > 16/14 nanometer – Apple, Qualcomm, MediaTek, Xilinx, Nvidia, AMD, IBM, HiSilicon, Spreadtrum
  - > 10 nanometer - Apple, Qualcomm, MediaTek, HiSilicon
  - > 7 nanometer - Apple, Qualcomm, MediaTek, Xilinx, HiSilicon, Lenovo, IBM, AMD

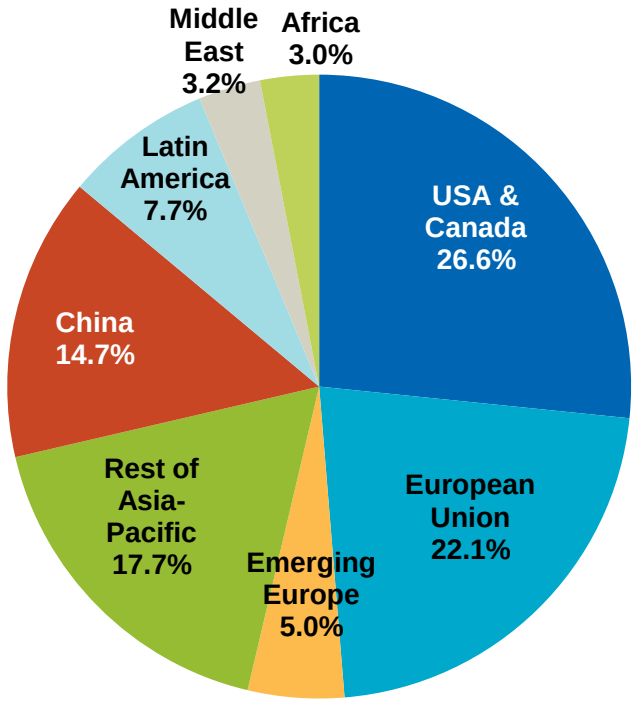
China Has Become a Global Economic Powerhouse

Top Ten Countries by GDP, Nominal



Source: IHS

Share of World GDP, Nominal (2015)



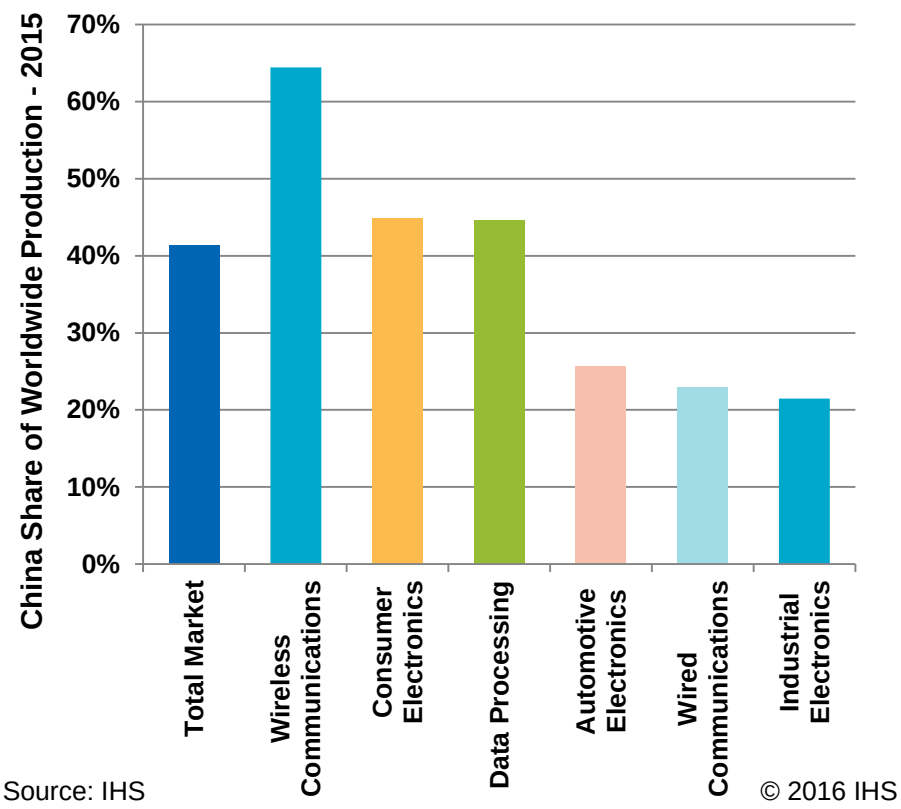
Source: IHS

2015 Total = $73.3 T

China has the largest economy outside of the US and is a leader in its region

China Dominates Production of Electronics: Local markets growing to complement exports

China's Share of WW Production



Production Trends

- Workforce, infrastructure & technology have driven high-quality / low-cost production centers and China dominance of electronics production
  - Foxconn is the modern driver of the "company town / city" in China
- Other countries such as the US have lost critical skills/abilities to compete in the world of manufacturing in many key sectors

Consumer and Mobile Electronics Production Revolve around China

China – Development of a domestic supply chain

- **Development of a semiconductor industry began with Project 909 in 2000**
  - > Semiconductor companies that were state owned were privatized
  - > HHNEC, SGNEC, ASMC were the initial companies founded as JV's with multinational companies
- **Technology development was limited due to US and Taiwan laws**
- **SMIC became the first company to successfully develop advanced technology using 300mm wafers**
  - > SMIC formed a JV with Elpida Memory in order to manufacture DRAM
- **China's goal: "Made in China Policy 2025"**
  - > 40% self-sufficient by 2020 and 70% self–sufficient by 2025

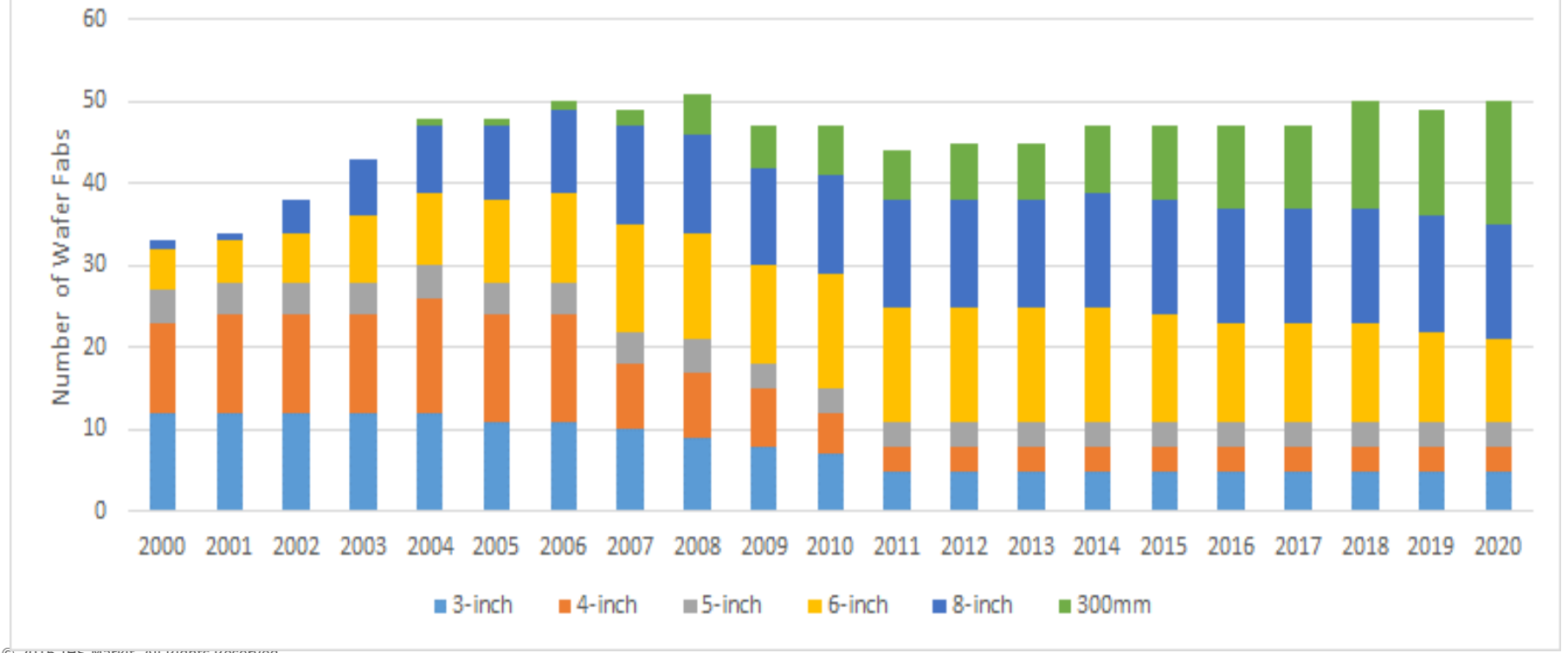
China – Global challenges facing China

- **China is the worlds largest purchaser of semiconductors accounting for more than 55% of global consumption**
  - > China is also the worlds largest exporter of electronics systems
- **China is aggressively adding capacity in order to manufacture components to reduce the volume of semiconductors imported**
- **Semiconductor technology manufactured in China's domestic fabs remains 3 generations the market leaders**
  - > Advanced technology accounts for more than half of China's semiconductor imports

Manufacturing expansions in China

- Expansion in Chinese wafer fabs is focused on 300 mm
  - > Technology deployment targets ranges from n-1 to legacy "More than Moore"

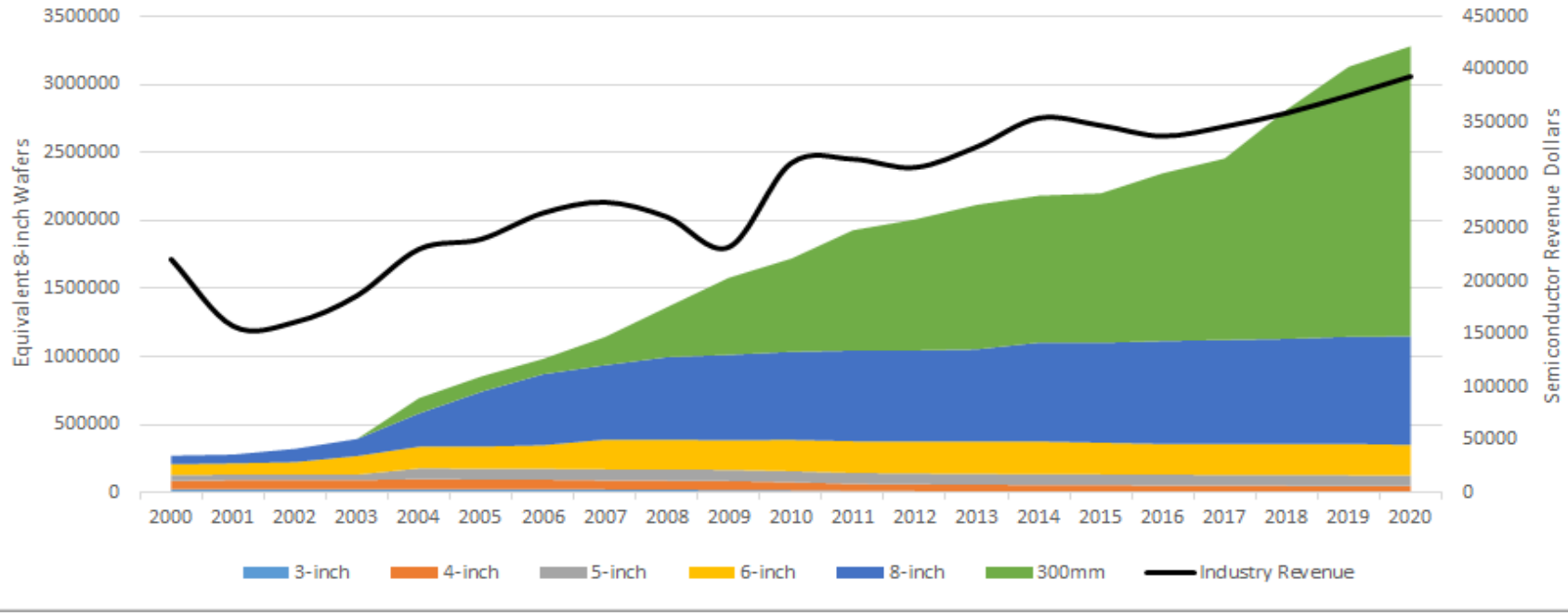
Wafer Fab Expansions by Year in China



Chinese wafer capacity expansions will outpace short-term demand

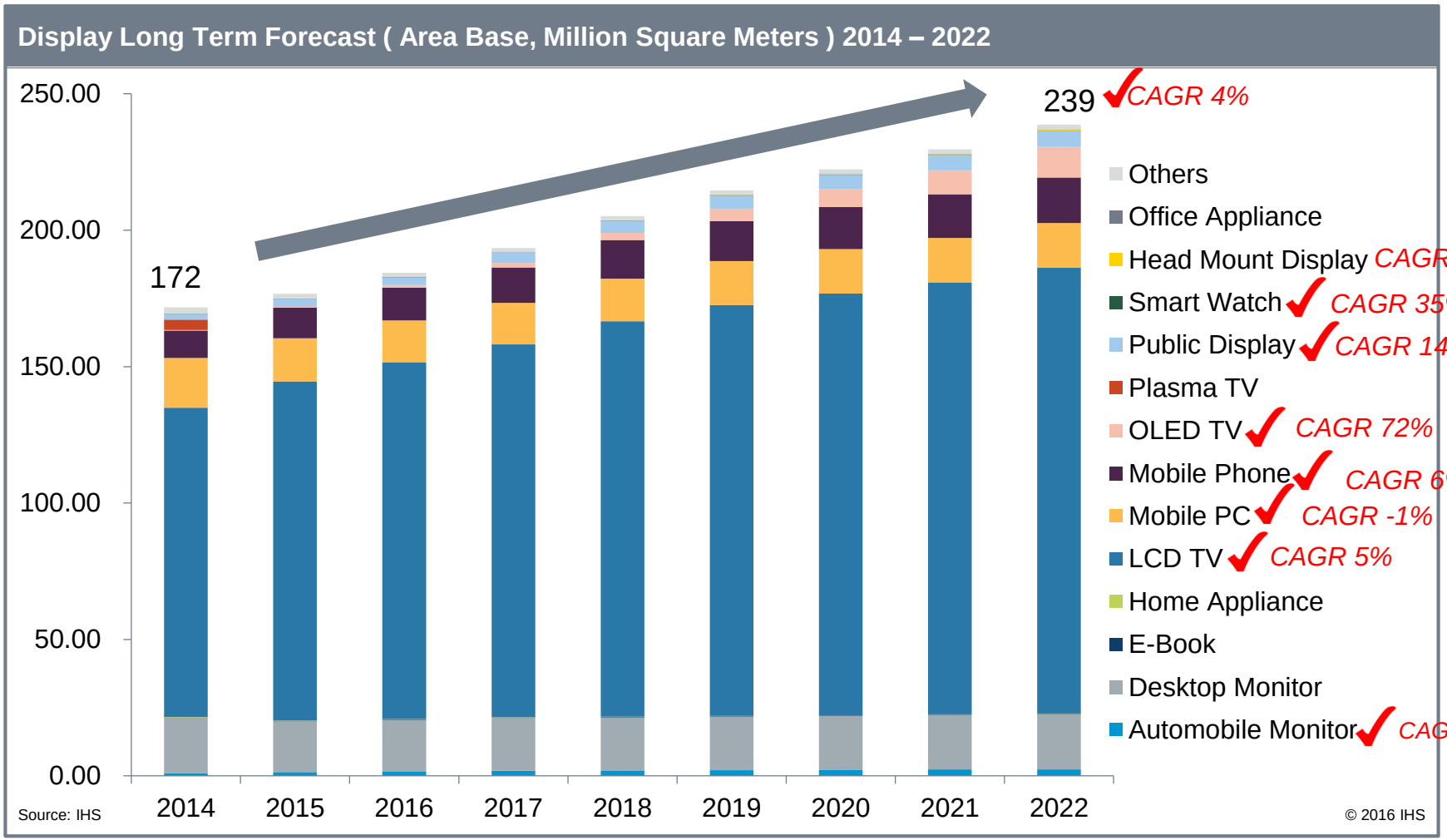
- Global semiconductor industry continues in a slow growth period through 2020 and possibly 2022
  - > Domestic demand must increase substantially in order to fill fab capacity beyond 2017

Forecasted Capacity Expansions within China and Global Semiconductor Industry Revenue



Displays

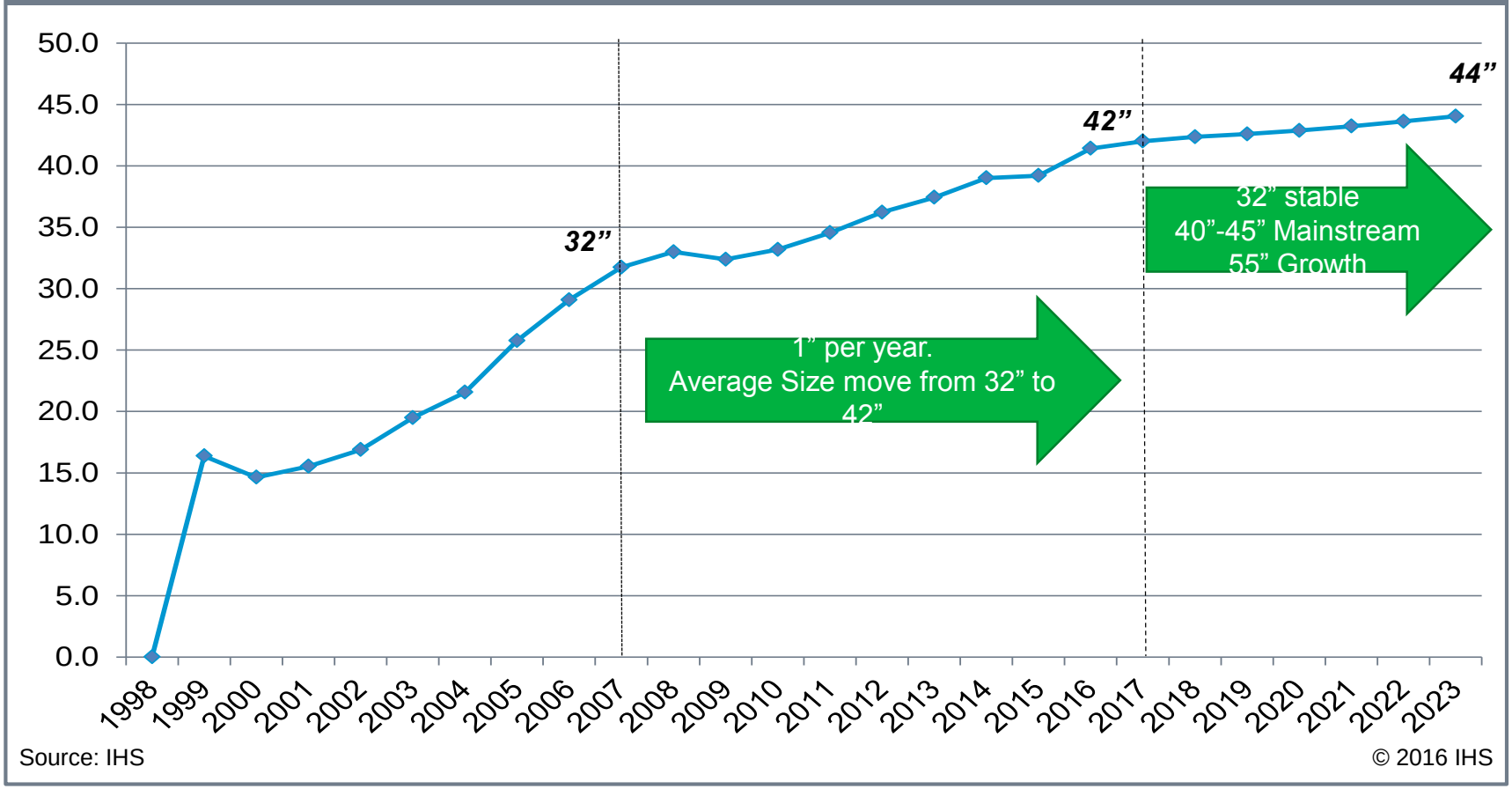
Demand Driven By TV Area & New Applications



Growth engine: Demand for larger size TV

- Big size jump within these years : 39.2”@2015, 41.4”@2016, 42”@2017
- 2016 : 4x” segment surpass 3x” segment. 2018: 6x” segment surpass 5%.

LCD TV Panel Average Size (inch)



Source: IHS

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Possible restructure/shutdown of fabs in 2016-2017

- Struggling financial issues, low utilization, and low efficiency push panel makers to shut down fabs.

Possible fab shutdowns, 2016-2017

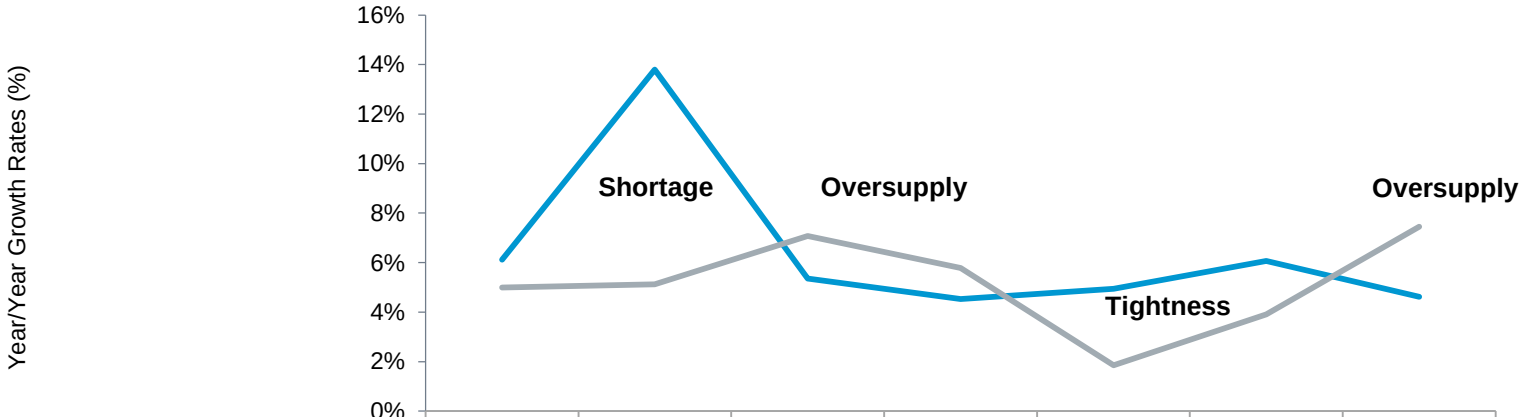
Panel Maker	Fab	Gen/Glass Size	Original Capacity	Tech.	Utilization now	Products	Ramp-up year	Depreciated Year	Original EOL Year
Samsung Display	L6	Gen 5	120K/M	a-Si	70-80%	Mobile	2003	2009	2018
	L7-1	Gen 7	155K/M	a-Si	95%	40” TV	2005	2011	2018
AUO	L3C	Gen 3.25	60K/M	a-Si	35%	Mobile	1999	2006	2017
	L4A	Gen 3.5	25K/M+ 35K/M Touch	a-Si	50-60%	Mobile, Touch	2001	2008	2017
	L3D	Gen 3.25	50K/M + 15K/M LTPS	a-Si	0%	Mobile, Touch	2001	2008	2015/End
	L5A	Gen 5	50K/M	a-Si	60-70%	Mobile, NB	2003	2009	
	L5D	Gen 5	75K/M	a-Si	50-60%	Mobile, NB	2003	2011	
Innolux	T0	Gen 4	20K/M	a-Si+EPD	50%	Mobile	2004	2009	2017
	T1	Gen 5	60K/M	a-Si	60%	Mobile	2004	2010	2018
	Fab1	Gen 3.25	70K/M	a-Si	60-65%	Mobile	1999	2005	2018
	Fab2	Gen 3.5	85K/M	a-Si	45-50%	Mobile	2001	2007	2018
	Fab3	Gen 5	145K/M	a-Si	85%	Mobile, NB	2003	2010	
LG Display	P2	Gen 3.25	85K/M	a-Si	52%	Mobile, NB	1997	2004	
	P3	Gen 3.5	92K/M	a-Si	50%	Mobile, NB	2000	2004	2018
	P4	Gen 5	150K/M	a-Si	65%	Mobile, NB	2002	2008	2019
	P5	Gen 5	100K/M	a-Si	62%	Mobile, NB	2002	2007	2018
BOE	B1	Gen 5	75K/M	a-Si	0%	Shift to MEMS	2004	2012	2016
	B2	Gen 4	45K/M	a-Si	Stop	Mobile	2008	2016	2016
CPT	T2	Gen 3.5	73K/M	a-Si	<20%	Mobile	2001	2007	2018
	T1	Gen 3	35K/M	a-Si	<50%	Mobile	1999	2006	
Sharp	Taki No.2C	Gen 3.5	45K/M	a-Si	<45%	Auto, Mobile	2000	2005	
	Taki CGS B	Gen 4	95K/M	a-Si, In-Cell	<50%	Mobile	2003	2010	2018
JDI	Mobara V3 LTPS	Gen 4	40K/M	LTPS	<50%	Mobile	2002	2012	2016
	STL Higashiura #1& #2	Gen 3.25	36K/M	LTPS+OLED	<50%	Mobile	1999	2007	2017

Source: IHS

Capacity Area Growth vs. Demand

- 1H'16 : Oversupply. 2H'16 : Tightness. The panel price increase in 2H'16 has somehow reflected the tightness in '17 and '18.
- 2017 and 2018 will be tight due to fab restructure and LCD TV area growth. To cope with the tightness, panel makers might have to pull in new fab construction schedules.
- In reality, the LCD TV demand will be influenced by the panel price increase in 2017-2018.

Display demand area growth vs. capacity area growth



	2013	2014	2015	2016	2017	2018	2019
LA LCD, AMOLED, AMEPD Demand Y/Y%	6%	14%	5%	5%	5%	6%	5%
TFT Capacity for AM Applications Y/Y%	5%	5%	7%	6%	2%	4%	7%

Inventory carried over from previous year

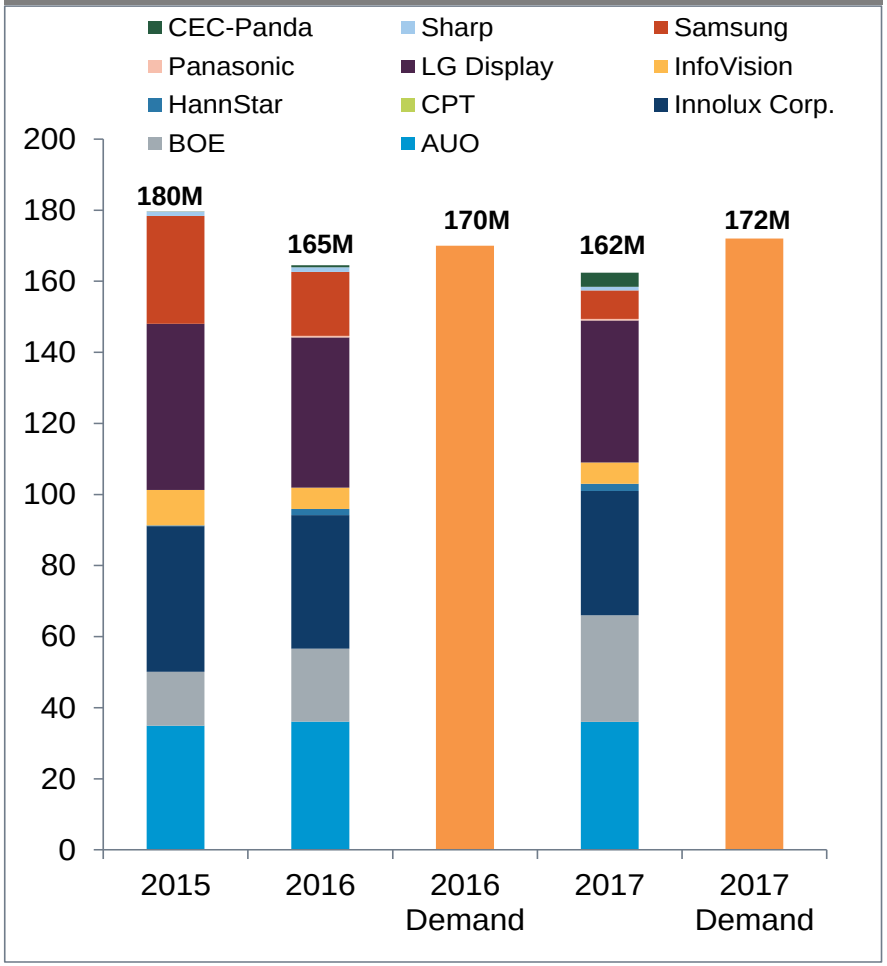
New TV size/area demand

Old fab restructure/shutdown

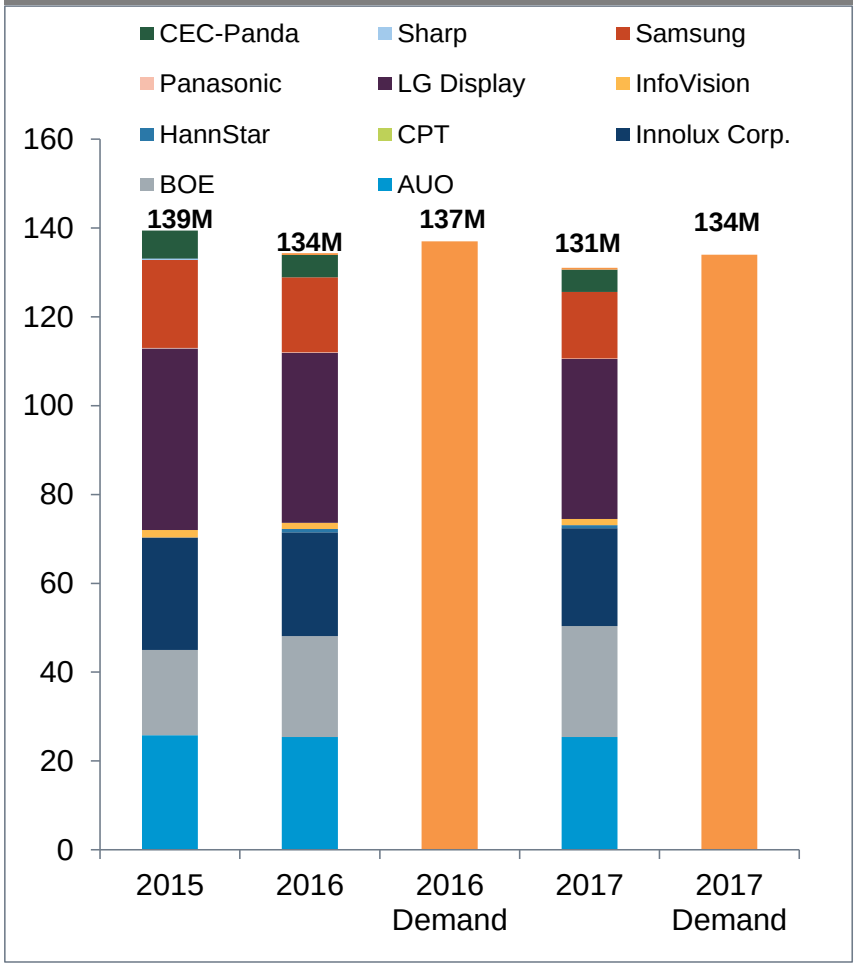
Source: IHS

NB and Monitor Panel Price Stabilize due to low supply

Notebook Panel vs. Demand (Million Units)

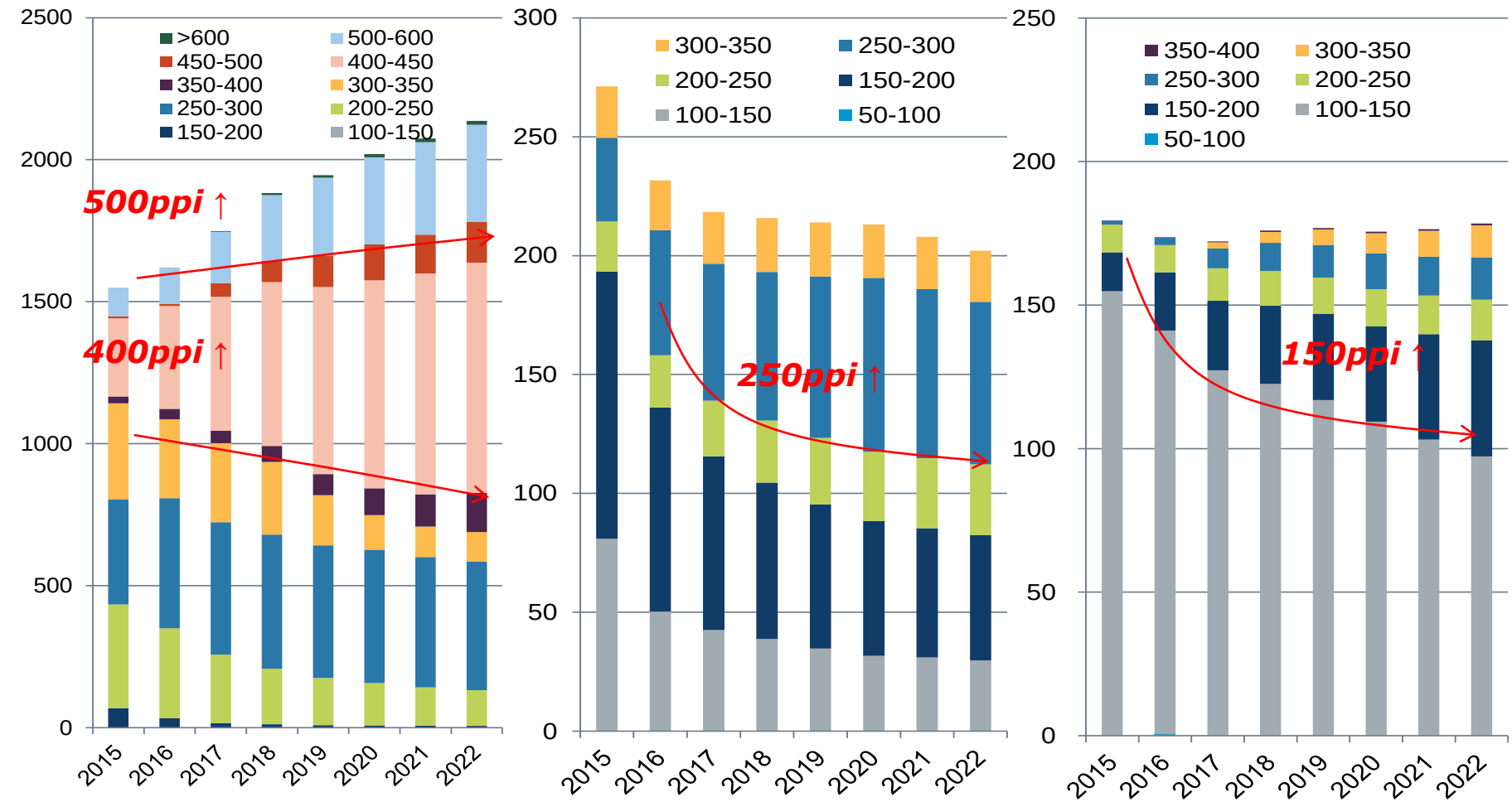


Monitor Panel vs. Demand (Million Units)



Growth engine: Higher resolution

Smartphone, Tablet & Notebook PPI Trend (million units)



Source: IHS

Model Name	Facebook Oculus Rift	HTC Vive Pre	Sony PlayStation VR	FOVE FOVE VR	Starbreeze StarVR
Photos	 Image credit: Oculus	 Image credit: HTC	 Image credit: Sony	 Image credit: FOVE	 Image credit: Starbreeze
Start Price	**$599**	**$799**	**$399**	**$500**	**TBC**
Launch Time	Mar'16	Apr'16	Oct'16	Q1'16	TBC (Acer)
Display pieces	2 pcs OLED	2 pcs OLED	2 pcs OLED	1pcs LCD	2 pcs LCD
Display	2 pcs 1080x1200 OLED 90mm (3.54'), 456 ppi	2 pcs 1080x1200 OLED 92mm (3.62'), 447 ppi	2 pcs 960x1080 ,3.x" = 1pics of 5.7" , each 960x1080, 387ppi	1pcs of 5.7" 2560 x 1440 LCD	2pcs of 5.5" (2160x1440) Total 5120 x 1440 LCD 472 ppi
Refresh Rate	90Hz	90Hz	120Hz	60Hz	90Hz

Samsung Display's UHD AMOLED prototype

Specifications:
Size: 5.5-inch diagonal
Resolution: 3840 × 2160
PPI: 806 ppi
Brightness: 350 nit
Color gamut: 97%
Pixel: RGB diamond PenTile

Source: Samsung Display – Photo taken by IHS at SID 2016 © 2016 IHS

VR display performance

Category	Micro Display		Flat Panel Display	
Technology	LCoS	OLEDoS	TFT-LCD	AMOLED
Size	< 1 inch	< 1 inch	> 1 inch	> 1 inch
Resolution	< Full HD	< Full HD	< Quad HD	< Quad HD
PPI	< 2,500 ppi	< 2,500 ppi	< 500 ppi	< 600 ppi
Brightness	150 nit	150 nit	400 nit	400 nit
Field of view	< 100	< 100	<120	< 120
Response time	> 10 µs	> 1 µs	> 10 µs	> 1 µs
Weight	< 7g	< 5g	< 30g	< 30g
Thickness	< 5 mm	< 5 mm	< 2.0 mm	<1.6 mm
Back light unit	Yes	No	Yes	No
Power consumption	< 350 mW	< 350 mW	< 700 mW	< 700 mW

Notes: All specifications are based on commercialized products, not prototypes.
Source IHS © 2016 IHS

Display is the most high-price component in VR device

Facebook Oculus Rift Tear-Down cost

Display cost = US$69 , 35% of the total BOM (Bill of Materials) Cost.

Oculus Rift Top Cost Drivers

Cost Summary	
Direct Material Costs (Component Costs)	$199.60
Conversion Costs *(Assembly / Insertion / Test Costs)*	$6.50
Total Cost ***(Direct materials and manufacturing)***	**$206.10**

Itemized Components	Manufacturer Name	Description	Total Cost
HEADSET			
Display			**$69.00**
AMOLED (x2)	SAMSUNG DISPLAY CO LTD	3.51" Diagonal, AMOLED, LTPS, 1200 x 1080, N/T, Pentile Matrix, 12.2g	
Processor ICs			**$3.11**
RF System-on-Chip	NORDIC SEMICONDUCTOR ASA	RF SoC, 2.4GHz RF Transceiver, 32-Bit ARM Cortex-M0 Core CPU, 128KB Flash, 16KB RAM, 8-Channel 10-Bit ADC, 31 I/Os	
Microcontroller	ST MICROELECTRONICS	MCU, 32-Bit, ARM Cortex-M0 Core, 48MHz, 128KB Flash & 16KB SRAM, 16-Channel 12-Bit ADC, 87 GPIOs	

AMOLEDs From Emerging to Mainstream

Examples of Recent Prototypes and Commercialized AMOLEDs


SDC Galaxy S6


LG G Watch


LGD 18″ Rollable


Apple Watch

LGE 77″

Skyworth 65″


SDC 55″ Transparent OLED
1920x1080, 45% transmittance


SDC 55″ Mirror OLED
1920x1080, 75% reflectance

Hisense 65″


12.3″ Samsung 2-in-1


OLED for automotive applications

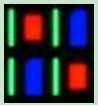
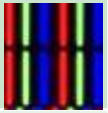
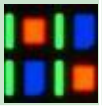
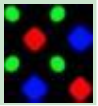
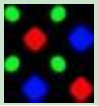
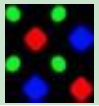
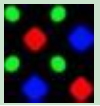
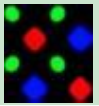
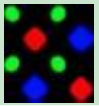
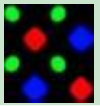
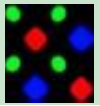

Dual-view curved tiling OLED

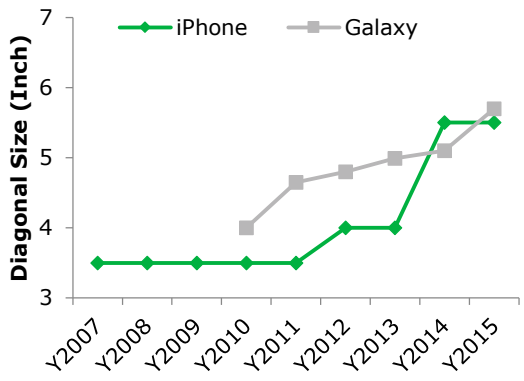
Dell 30″ OLED Monitor

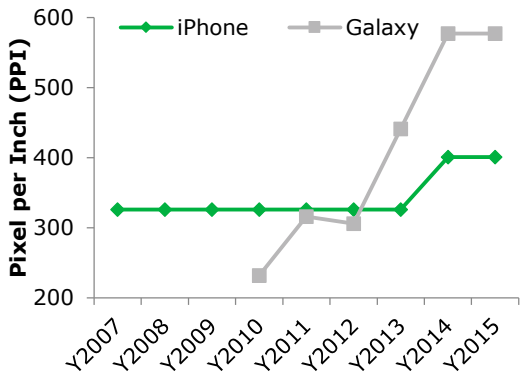
Source: Makers, IHS

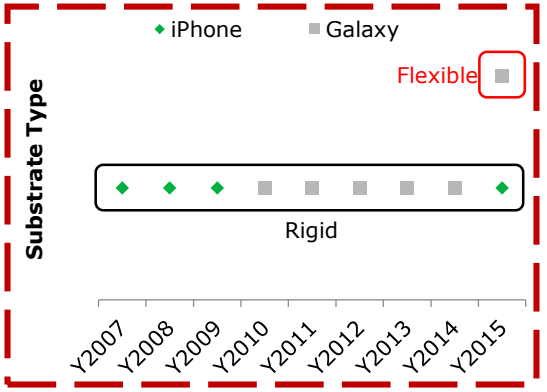
Technology Trend for Smartphone OLED

History of Galaxy S Series' AMOLED specification

Vs.	Galaxy S	Galaxy S2	Galaxy S2 LTE	Galaxy S2 HD LTE	Galaxy S3	Galaxy S4	Galaxy S5	Galaxy S5 Prime	Galaxy S6	Galaxy S6 Edge	Galaxy S6 Edge+	Galaxy S7	Galaxy S7 Edge
Launching	Mar. 2010	Apr. 2011	Sep. 2011	Nov. 2011	May. 2012	Mar.2013	Mar.2014	Jun.2014	Mar.2015	Apr.2015	Aug. 2015	Mar. 2016	Mar. 2016
Diagonal Size	4.0″	4.3″	4.5″	4.65″	4.8″	4.99″	5.1″	5.1″	5.1″	5.1″	5.7″	5.1″	5.5″
TSP	On-Cell	On-Cell	On-Cell	On-Cell	On-Cell	On-Cell	On-Cell	On-Cell	On-Cell	P1S	A-P1S	On-Cell	A-P1S
Resolution	800 x 480 / WVGA	800 x 480 / WVGA	800 x 480 / WVGA	1280 x 720 / WXGA	1280 x 720 / WXGA	1920x1080 / Full HD	1920 x 1080 / Full HD	2560 x 1440 / Quad HD	2560 x 1440 / Quad HD	2560 x 1440 / Quad HD	2560x1440 / Quad HD	2560 x 1440 / Quad HD	2560 x 1440 / Quad HD
PPI	232	217	207	316	306	441	432	577	577	577	515	577	534
Real PPI	154	217	207	210	204	294	288	385	385	385	342	377	342
Substrate	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid	Flexible	Flexible	Rigid	Flexible
Pixel Type	Pentile	RGB Stripe	RGB Stripe	Pentile	Pentile	S-Pentile	S-Pentile	S-Pentile	S-Pentile	S-Pentile	S-pentile	S-Pentile	S-Pentile
Microscope View (4 pixels)													
# of Sub pixels	8	12	12	8	8	8	8	8	8	8	8	8	8







Source: IHS

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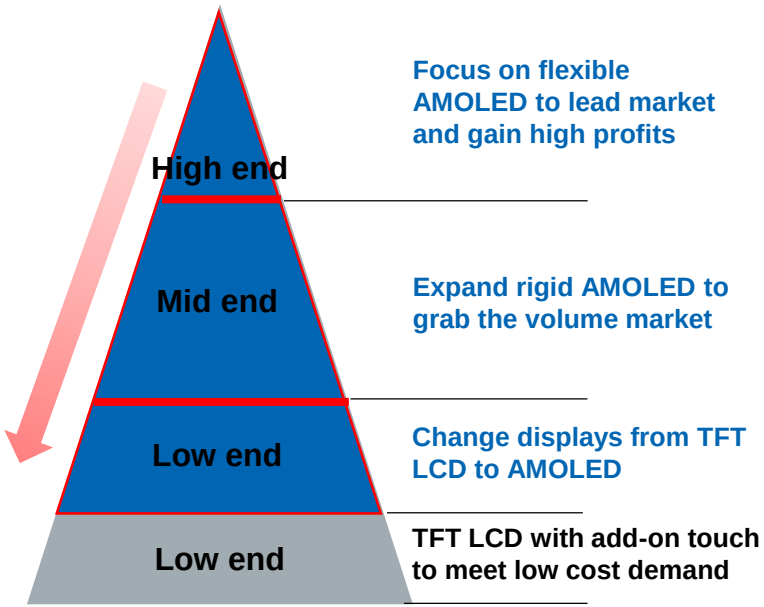
(Source : IHS Report, 'OLED Strategy, Technology & Market – 2015')

OEMs increasing AMOLED panel adoption

- Samsung's product lineup change and demand for Chines brands impact the AMOLED market growth.

Samsung smartphone strategy in 2015-2016



Source: IHS

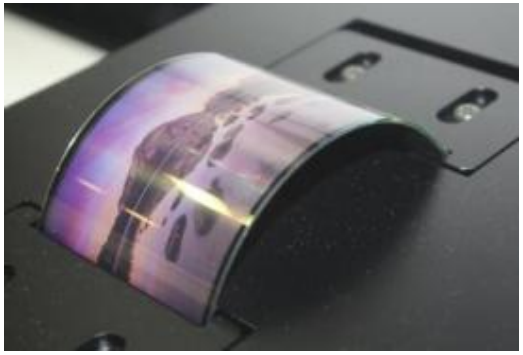
Overseas brands' AMOLED smartphones

	2014	2015	2016
Model	21 models	over 50 models (55M panels)	over 50 models (100M panels)
Brand	Motorola, Nokia, Lenovo, OPPO, VIVO, Gionee	**OPPO, VIVO**, **Gionee**, Micromax, Meizu, WIKO, Huawei, Microsoft,	**OPPO, VIVO**, **Gionee**, Micromax, **Meizu**, WIKO, **Huawei**, Xiaomi, Microsoft, BB, HP, Hisense, Konka
Product	High-end	Mid to high-end	Mid to high-end
Display	4.x-5.x"	4.x-6.0"	4.x-6.0"
Resolution	HD, FHD	HD, FHD, WQHD	HD, FHD, WQHD
Substrate	Rigid AMOLED	Rigid AMOLED Started to supply flexible AMOLED from Q4 2015	Rigid AMOLED Increase flexible AMOLED

Source: IHS

Flexible OLED in SID 2016

JDI Curved 5.2” FHD



Source: IHS © 2015 IHS

LG Display Curved 12.3” FHD

Source: IHS © 2015 IHS

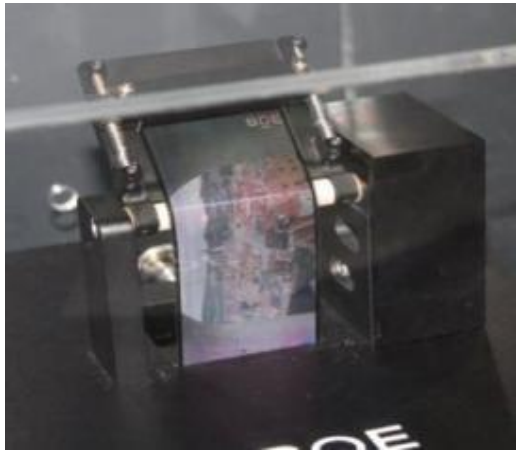
Tianma Bendable 5.5” FHD

Source: IHS © 2015 IHS

Samsung Display Rollable 5.7” FHD

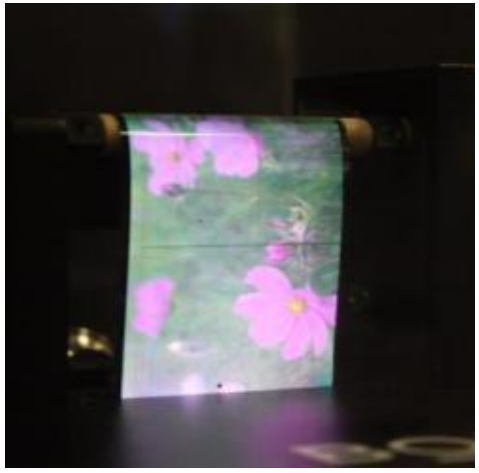
Source: IHS © 2015 IHS

BOE Bendable 4.35” WVGA



Source: IHS © 2015 IHS

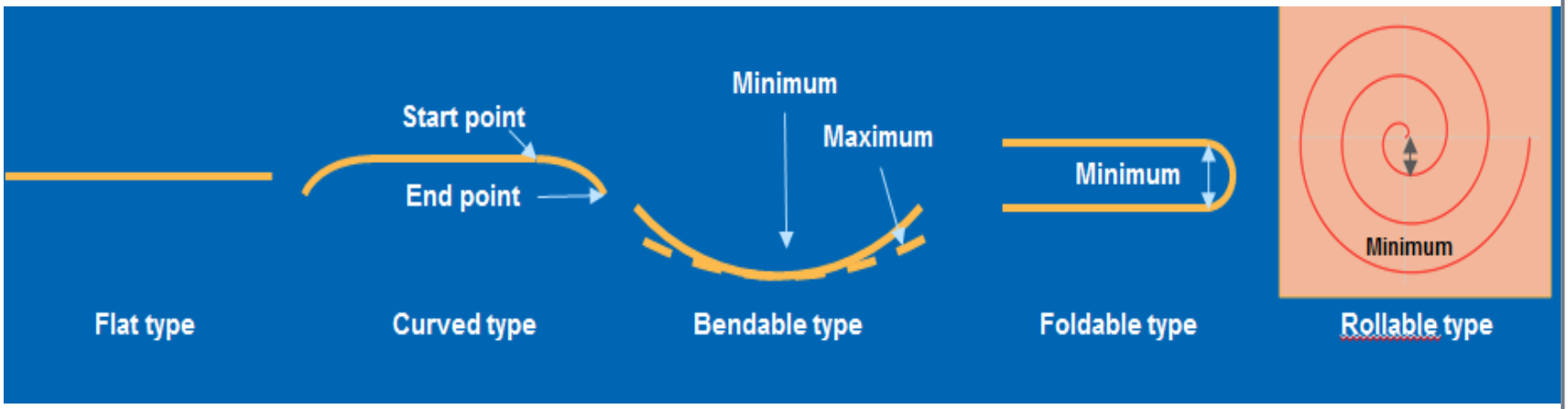
BOE Foldable 4.35” WVGA

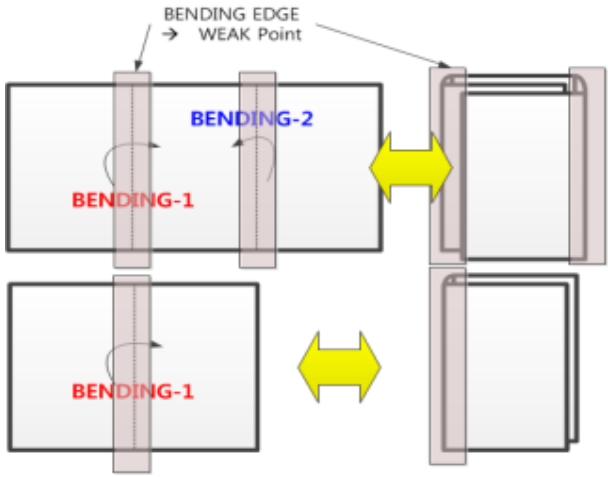


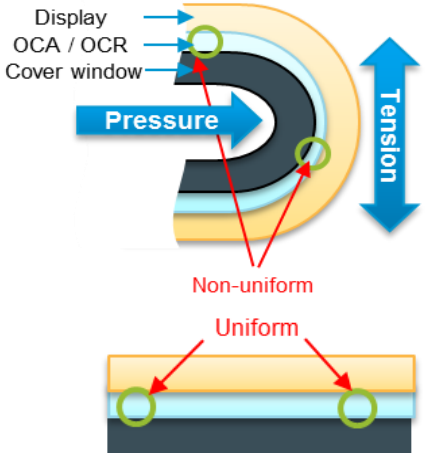
Source: IHS © 2015 IHS

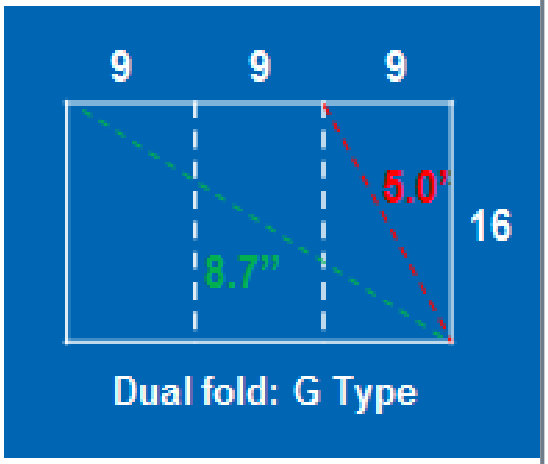
Considering Foldable Application

Types of flexible display by bending radius and folds









Source: IHS

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Flexible OLED : Nice to Have or must have?

Nice but many substitutes
good enough

No substitutes.
Make people buy no matter how much it costs

Flexible OLED

Semiconductor & Display Trends

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